BRIDGE ALTERNATIVES EVALUATION AND LIFE CYCLE COST COMPARISION

for

BRIDGE STREET

over

MITCHELL RIVER

BRIDGE NO. C-07-001 (437)

DISTRICT 5

CHATHAM

MASSACHUSETTS

Prepared for:

Commonwealth of Massachusetts

Department of Transportation – Highway Division

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APRIL 28, 2011

1.0 EXECUTIVE SUMMARY

The existing Mitchell River Bridge (Bridge Number C-07-001 (437)) in Chatham, Massachusetts, which is owned and maintained by the Town of Chatham, is being considered for replacement under the Massachusetts Department of Transportation (MassDOT) Accelerated Bridge Program. This project would be supported in part with Federal funding through the Federal Highway Administration (FHWA) and, therefore, is subject to review under Section 106 of the National Historic Preservation Act of 1966, as amended [36 CFR 800].

As part of the Section 106 Process, FHWA and MassDOT submitted documentation to the State Historic Preservation Officer (SHPO) requesting formal determination of the Mitchell River Bridge's eligibility for listing in the National Register of Historic Places (NRHP). In 1984, 1985, and more recently in January, February, and July 2010, SHPO determined that the bridge was not eligible for listing in the NRHP. However, in October 2010, the Keeper of the NRHP overturned the earlier SHPO findings and subsequently determined that the bridge is eligible for listing in the NRHP. The Keeper found that the existing Mitchell River Bridge was a "rare example" and "of exceptional significance as the last remaining single-leaf wooden drawbridge in Massachusetts (and perhaps the entire United States)" and "an exceptionally important part of the community's historic identity."

An earlier report titled *Bridge Repair/Rehabilitation Feasibility Study for Bridge Street over Mitchell* River dated March 10, 2011, contains information regarding the condition of the existing bridge. The evaluation concluded that although technically feasible, it is not prudent to rehabilitate the existing bridge, and contained a recommendation that the existing bridge be replaced.

Since the Keeper of the NRHP has determined the bridge is eligible for individual listing in the National Register, FHWA and MassDOT acknowledge that replacing the bridge could result in an adverse effect under Section 106, as defined by the Code of Federal Regulations, 36 CFR 800.5(a)(1). This study, therefore, evaluates bridge replacement alternatives that could avoid, minimize, or mitigate the adverse effect, as required by 36 CFR 800.6(a). MassDOT specified development, evaluation and comparison of the following five (5) viable bridge replacement alternatives:

- Alternative 1: Timber Superstructure on Timber Substructure with Timber Bascule Span (i.e. All Timber Replacement)
- Alternative 2: Timber Superstructure on Timber Substructure with Steel Bascule Leaf on Concrete Bascule Pier
- Alternative 3: Timber Superstructure on Concrete and Steel Substructure with Steel Bascule Leaf on Concrete Bascule Pier
- Alternative 4: Timber Deck and Steel Stringer Superstructure on Concrete and Steel Substructure with Steel Bascule Leaf on Concrete Bascule Pier
- Alternative 5: Concrete Deck and Beam Superstructure on Concrete and Steel Substructure with Steel Bascule Leaf on Concrete Bascule Pier

The evaluation of the replacement alternatives considers numerous factors including roadway function and safety; avoidance, minimization and mitigation of adverse effect to the NRHP eligible resource; navigation function and safety; initial construction and life cycle costs; maintenance and reliability; property impacts; disruptions to users; and environmental impacts. The following project design criteria have been established so that the replacement Mitchell River Bridge would generally:

- Meet current design criteria and standards for functionality and safety for all users; traffic railings that separate the sidewalks from the roadway for protection of pedestrians from vehicular traffic; sidewalks that meet accessibility and safety standards; adequate load carrying capacity.
- Provide a context sensitive design that is appropriate for the site and character of the Town of Chatham, and serves to mitigate the adverse affect of replacement of the NRHP eligible resource consistent with the Section 106 Process.
- Improve navigation safety and reliability by providing a wider navigation opening than the existing 19’-4” clear width between fenders and 15’-2” clear width with unlimited vertical clearance between east fender and tip of raised bascule leaf; preferably provide a 25’-0” wide horizontal opening between fenders with unlimited vertical clearance; maintain, as a minimum, the existing vertical clearance under the bridge in the closed position.
- Provide a cost effective design with service life of at least 75 years (or similar overall life cycle costs) with low maintenance costs.
- Minimize future maintenance, improve operational safety and reliability, and reduce operating duration, to minimize disruptions to all users.
- Minimize environmental impacts both during construction and throughout the bridge service life, and provide a design that will be permitted by the various environmental agencies.
- Address the deteriorated condition of the existing bridge, such that the bridge is removed from the Structurally Deficient List.

The matrix below summarizes how well each alternative satisfies each of the above primary project design criteria. The evaluation is graded on the following scale: *Good*, *Satisfactory*, *Fair*, and *Poor*, in order of best to worst in satisfying these criteria:

RESULTS OF DESIGN CRITERIA EVALUATION							
Alt.	Primary Project Design Criteria Categories						
	Roadway Function & Safety(1)	Context Sensitive(2)	Navigation Function & Safety(3)	Initial Construction Cost(4)	Life Cycle Costs(5)	Maintenance & Service Life(6)	Environment (7)
1	Good	Good	Poor	Good	Fair	Poor	Poor
2	Good	Satisfactory	Good	Fair	Poor	Fair	Fair
3	Good	Fair	Good	Fair	Satisfactory	Satisfactory	Satisfactory
4	Good	Fair	Good	Fair	Satisfactory	Satisfactory	Satisfactory
5	Good	Poor	Good	Satisfactory	Good	Good	Satisfactory

Notes:

1. Alternatives 1 thru 5 equally accommodate improvements in roadway function and safety, including additional roadway and sidewalk width and safety features.
2. Alternative 1 is an all timber solution that would resemble the existing bridge. The other alternatives contain timber in different bridge elements and other features that mitigate the replacement of the NRHP eligible resource. See table below.

CONTEXT SENSITIVE SOLUTIONS - SUMMARY OF BRIDGE ELEMENTS with TIMBER							
Alt.	Approach Substructure	Approach Beams	Deck	Sidewalks	Pedestrian Railings	Traffic Railings	Bascule Span
1	✓	✓	✓	✓	✓	✓(E)	✓
2	✓	✓	✓	✓	✓	✓(E)	✗ (D)
3	✗	✓(E)	✓	✓	✓	✓(E)	✗ (D)
4	✗	✗ (A)	✓	✓	✓	✓(E)	✗ (D)
5	✗	✗ (B)	✗ (C)	✓	✓	✓(E)	✗ (D)

Notes:

A. Steel stringers are obscured by the timber sidewalks.
B. Concrete deck beams are obscured by the timber sidewalks.
C. Concrete deck includes a stamped concrete pattern and color admixtures to simulate a timber deck.
D. Concrete bascule pier contains stone facing and steel bascule leaf is obscured by the timber sidewalk.
E. Denoted timber members are glue laminated (i.e. glulam) timber in lieu of sawn lumber.

3. A letter from the United States Coast Guard dated February 12, 2010, states "… there have been numerous structural and operational issues involving this bridge over the past several years. A design flaw in the original construction of the bridge prevented it from fully opening for passage of vessel traffic resulting in several mishaps wherein vessels sustained damage to their rigging due to hitting the tip of the draw span. <u>In its present condition the draw span cannot fully open to provide unobstructed vertical clearance for the full width of the bridge between fender faces. The Coast Guard, therefore, will seek to promote the optimum navigational opening for any proposed replacement structure</u>." Alternative 1 provides only a 19'-4" navigation opening width with unlimited clearance, which would be unacceptable to the boating community, and includes non-redundant operating machinery possessing safety and reliability concerns. Alternatives 2, 3, 4 and 5 provide a 25'-0" navigation opening width with unlimited clearance, which is preferred by the boating community and redundant operating machinery that provides a higher degree of safety and reliability.
4. Alternative 1 has a low initial construction cost, Alternatives 2, 3 and 4 have high initial construction costs, and Alternative 5 has a moderate initial construction cost.
5. Per the life cycle cost analysis, Alternative 1 has moderate to high life cycle costs, Alternative 2 has a high life cycle costs, Alternatives 3 and 4 have moderate life cycle costs, and Alternative 5 has low overall life cycle costs. With the exception of the initial construction costs, which will be funded under the Accelerated Bridge Program, the Town of Chatham is assumed to be responsible for all other life cycle costs.
6. Alternative 1 provides a relatively short service life requiring complete replacement of the bridge, except for the concrete abutments, every 20 to 30 years, due to the need to replace the timber piles. Alternative 2 provides a relatively short service life for

the approach spans requiring replacement of the approach spans every 20 to 30 years, due to the need to replace the approach span timber piles. Alternatives 3, 4, and 5 provide significantly greater service life requiring replacement of concrete and steel elements only after 80 to 100 years, although replacement of timber elements are required more frequently. Alternatives 1, 2, 3, and 4 require replacement of the timber wearing surface every 10 to 20 years and replacement of the timber structural deck every 20 to 40 years, where Alternative 5 requires only resurfacing of the concrete after 40 years. Each instance the bridge, approach spans, deck, and wearing surface are replaced result in significant disruptions to users, with corresponding user delay costs.

7. Alternatives 1 and 2 include timber piles that will require replacement on more frequent intervals. Replacement of piles disturbs the waterway bottom sediments, which contain accumulations of polycyclic aromatic hydrocarbons (PAHs) and other compounds from the existing piles that are toxic to aquatic organisms. Alternatives 1 and 2 contain a significantly greater number of piles and pile bents than Alternatives 3, 4 and 5, and thus disturb a greater volume of bottom sediments during pile replacement. Although, the concrete bascule pier for Alternatives 2, 3, 4 and 5 is large, the steel sheet pile cofferdam used to construct the pier will contain the sediments and minimize impacts of the disturbed sediments on the environment. New timber piles and other submerged timber substructure elements for Alternatives 1 and 2 may also include timber preservative treatments that are considered hazardous to human health and the environment. Alternatives 3, 4 and 5 include piles and substructure elements with a significantly greater service life and thus minimize the occurrences when the bottom sediments would be disturbed. The piles and submerged substructure elements of Alternatives 3, 4 and 5 avoid the need for hazardous timber preservatives.

Based on evaluation and comparison, the alternatives are generally ranked as follows with regard to the project design criteria:

RANK	ALTERNATIVE
1	Alternative 5
2	Alternative 3
3	Alternative 4
4	Alternative 2
5	Alternative 1

Alternative 5 appears to best satisfy the overall project design criteria. Alternative 5 meets roadway function and safety requirements, minimizes impacts to adjacent properties, provides a cost-effective solution with the lowest overall life-cycle costs, requires least amount of maintenance and corresponding fewest disruptions to users, fully addresses navigation function and safety needs, minimizes impacts to the environment, and provides a context sensitive solution with features that seek to mitigate the replacement of the NRHP eligible resource.

Alternatives 3 and 4 also meet roadway function and safety requirements, minimize impacts to adjacent properties, fully address navigation function and safety needs, and minimize impacts to the environment. In addition, Alternatives 3 and 4 provide a modestly more context sensitive solution than Alternative 5, given the use of timber bridge deck in lieu of concrete bridge deck. However, Alternatives 3 and 4 require greater maintenance with corresponding greater disruptions to users, a higher initial construction cost, and higher life-cycle costs. Alternatives 3 and 4 are virtually equal to each other in construction cost, life-cycle costs, and in meeting project design criteria. However, Alternative 3 provides a slightly more context sensitive solution than Alternative 4 with the use of approach span timber stringers in lieu of approach span steel stringers.

Alternative 2 also meets roadway function and safety requirements, minimizes impacts to adjacent properties, and fully addresses navigation function and safety needs. In addition, Alternative 2 provides a more context sensitive solution than Alternatives 3, 4 and 5 with the use of all timber approach span superstructure, substructure and pile foundations. However, Alternative 2 requires significantly greater maintenance with corresponding disruptions to users, introduces greater environmental impacts, and has the highest initial construction cost, and highest life-cycle costs.

Alternative 1 also meets roadway function and safety requirements and minimizes impacts to adjacent properties. In addition, Alternative 1 has the lowest initial construction cost and is the only solution that provides an all timber single-leaf wooden draw span. However, Alternative 1 has moderate to high life-cycle costs, does not adequately address navigation function and safety needs, requires significantly greater maintenance and corresponding disruptions to users, and introduces the greatest environmental impacts.

As such, URS recommends Alternative 5 is recommended with continued coordination of appropriate mitigation to achieve an appropriate balance of all design criteria.

2.0 INTRODUCTION

The existing Mitchell River Bridge (Bridge Number C-07-001 (437)) in Chatham, Massachusetts, which is owned and maintained by the Town of Chatham, is being considered for replacement under the Massachusetts Department of Transportation (MassDOT) Accelerated Bridge Program. This project would be supported in part with Federal funding through the Federal Highway Administration (FHWA) and, therefore, is subject to review under Section 106 of the National Historic Preservation Act of 1966, as amended [36 CFR 800].

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3.0 ALTERNATIVES EVALUATION

Bridge solutions are required to meet the project design criteria including various design standards, goals, objectives and commitments. However, it is sometimes not feasible to meet one or more specific criteria due to conflicting criteria and/or constraints. Where it is not feasible to meet specific design criteria, justification must be provided to document the reasons why the criteria cannot be met and demonstrate that the result from the solution do not introduce unacceptable conditions or adverse impacts.

Initial screening of bridge replacement solutions identified that there is no single solution that meets all project design criteria. Several viable alternatives have been identified that meet most of the project design criteria, but do not meet one or more of the design criteria. This study evaluates and compares the viable alternatives to determine which solution best meets the project design criteria and results in the fewest overall impacts.

3.1 Evaluation Criteria

The evaluation of the replacement alternatives considers numerous factors including roadway function and safety; avoidance, minimization and mitigation of adverse effect to the NRHP eligible resource; navigation function and safety; initial construction and life cycle costs; maintenance and reliability; property impacts; disruptions to users; and environmental impacts. The following project design criteria have been established so that the replacement Mitchell River Bridge would generally:

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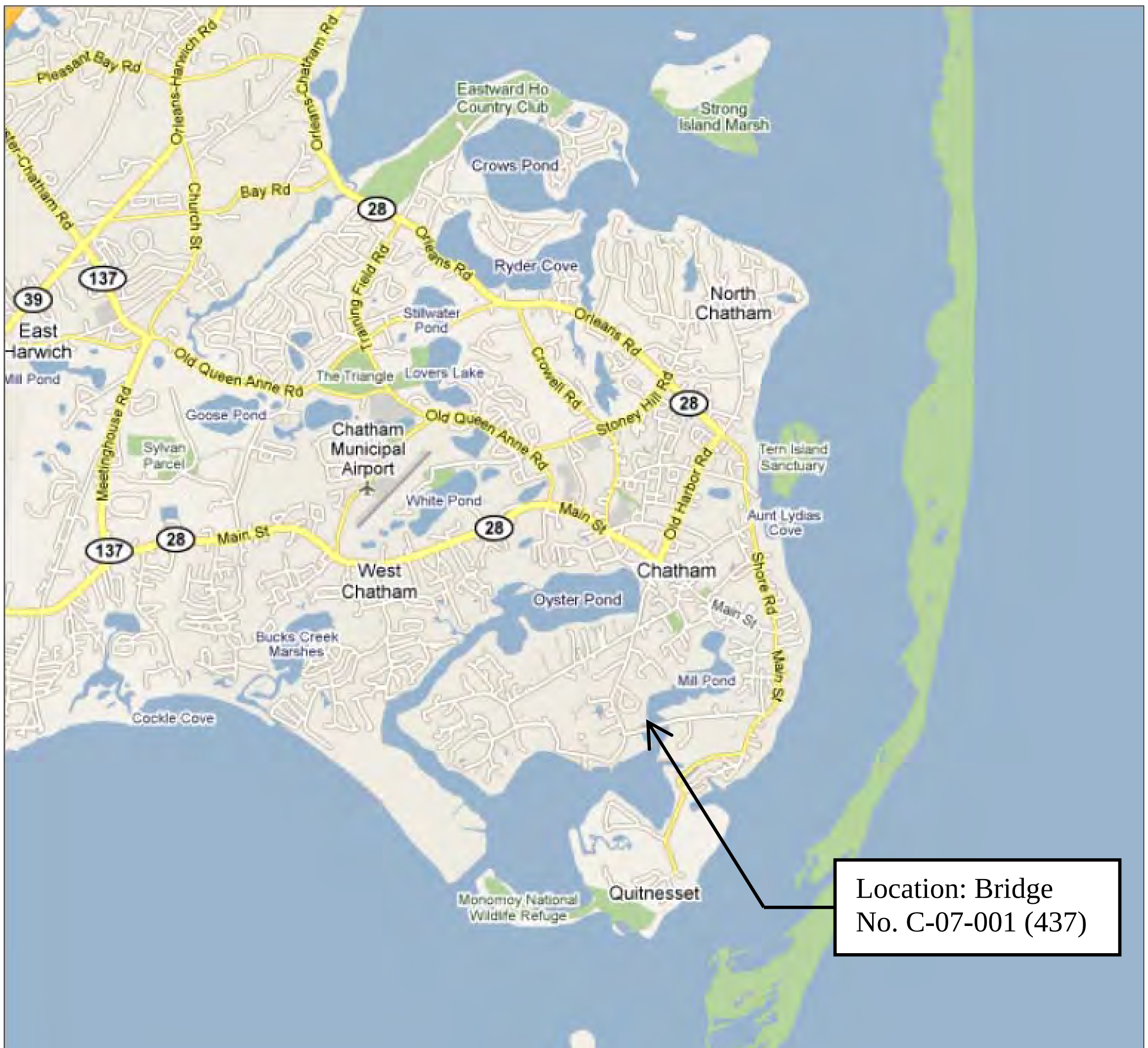
- Address the deteriorated condition of the existing bridge, such that the bridge is removed from the Structurally Deficient List.

3.2 Common Criteria, Features and Constraints

The design, information, criteria and constraints described below apply equally to all alternatives and thus are not discussed, evaluated and compared separately for each of the alternatives.

3.2.1 General

The Mitchell River Bridge carries Bridge Street over the Mitchell River located between Stage Harbor Road and the intersection of Main Street and Morris Island Road in the Town of Chatham. Bridge Street is a two-lane local road with two-way traffic and is classified as an Urban Collector with Average Daily Traffic (ADT) of 2,100 vehicles of which approximately 6% are trucks.



PROJECT LOCATION MAP

3.2.2 Character-Defining Historic Features

The character-defining features that make the existing bridge eligible for listing in the NRHP is that the bridge is “one of a continuous line of wooden drawbridges that have spanned this crossing for over 150 years” and “the last remaining single-leaf wooden drawbridge in Massachusetts (and possibly the United States).”

PHOTO - EXISTING BRIDGE SOUTH ELEVATION

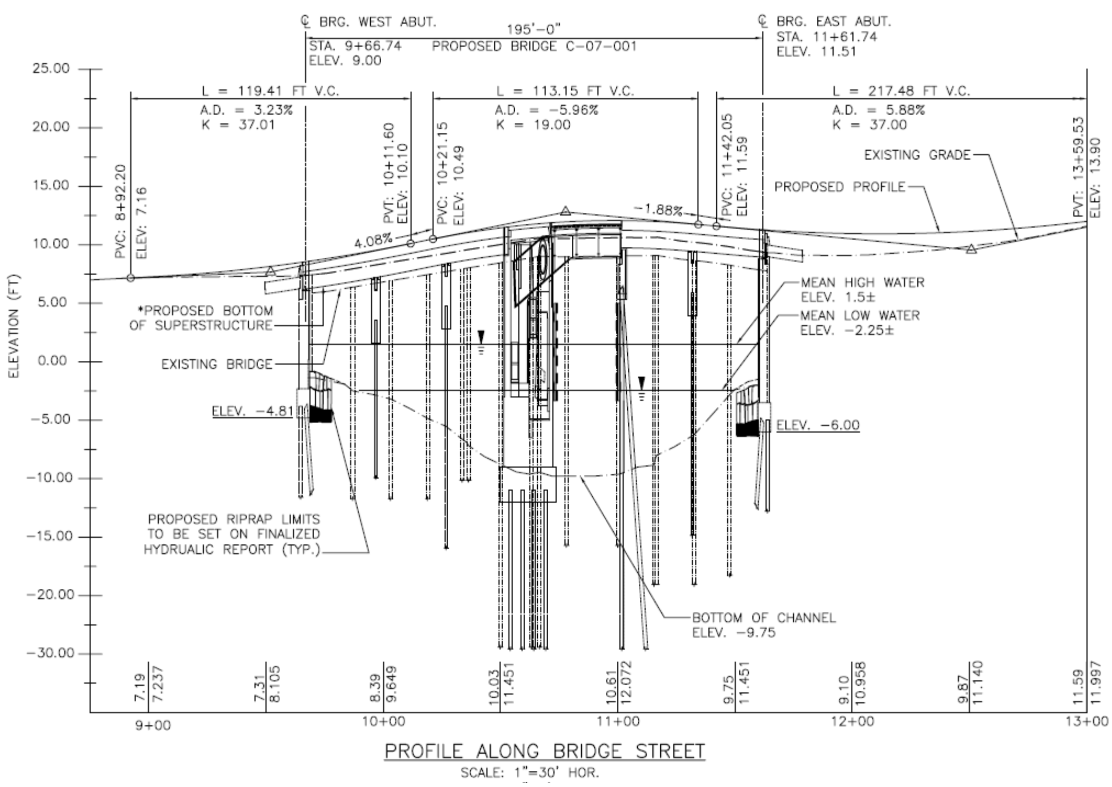
3.2.3 Typical Section

The proposed bridge typical section to be used for all replacement alternatives is based on a 30 mph design speed and includes a 26’-0” clear roadway width, 5’-0” raised timber sidewalks located on each side of the roadway behind crash tested timber traffic railings meeting the requirements of AASHTO and NCHRP 350, and 3’-6” high timber post and beam pedestrian railings at the back of sidewalk. The bridge will have an overall width of 40’-11”. The 26’-0” roadway accommodates two 11’-0” lanes with 2’-0” shoulders each side. The 2’-0” shoulders were reduced from previous 4’-0” bike lanes at the request of the Town of Chatham and supported by the Bikeways Committee. Currently there are no bike lanes along Bridge Street. The bridge deck will either have a crowned section with 1/4” per foot cross slope for drainage on concrete deck alternatives or level cross slope for timber deck alternatives. The bridge sidewalks will provide a 5’-0” clear width the length of the bridge and will meet accessibility requirements.

The typical section for the roadway will match the bridge typical section for all replacement alternatives for a length of approximately 120 feet beyond each end of the bridge where the roadway will meet the existing roadway section. The roadway typical section will include a 26’-0” clear roadway width, 5’-0” raised concrete sidewalks located each side of the roadway behind curb and gutter, crash tested guardrail meeting the requirements of AASHTO and NCHRP 350 and located at the curbs, and 3’-6” high timber post and beam pedestrian railings at the back of sidewalk along the abutment wing walls. The approach sidewalks will provide a 5’-0” clear width the length of the approach roadway and will meet accessibility requirements.

3.2.4 Roadway Geometry

The proposed roadway horizontal alignment and vertical profile will avoid or minimize impacts to the adjacent environmental resources (salt marsh on the east and west end of the bridge, shellfish growing areas north and south of the bridge), adjacent structures (fish storage shed on the southwest quadrant), and layout lines. The replacement bridge will be located on a straight (tangent) alignment approximately matching the alignment as the existing bridge. The roadway vertical profile will be raised as much as practical, although the ground elevation adjacent to the existing fish storage shed and the minimum length of vertical crest and sag curves for the specified design speed restricts the amount that the roadway profile can be raised. The height of the roadway profile at the center of the navigation channel can be raised approximately 18" relative to the existing profile. The proposed roadway vertical profile across the bridge will be asymmetrical due to the difference in height of the roadway approaching each end of the bridge with a +4.08% maximum approach grade from the west and -1.88% maximum departure grade to the east. The vertical curve lengths will be as recommended by AASHTO for minimum stopping sight distances for the design speed (K_{crest} = 19 and K_{sag} = 37). The existing 7'-4" clearance above MHW over the navigation channel will be maintained for all replacement alternatives.



PROPOSED ROADWAY GEOMETRY

3.2.5 Bridge Length and Span Arrangement

The existing bridge is approximately 192 feet long from abutment to abutment. The replacement bridge will be approximately the same length, but may vary slightly (only 2 to 3 feet) to accommodate uniformity in the span lengths. The bridge will consist of a multi-span trestle structure with the number of spans varying depending on the alternative. All alternatives will include a single-leaf bascule span over the navigation channel located in approximately the same location as the existing navigation channel.

3.2.6 Traffic Control

Traffic is controlled during bridge operations using electrically operated horizontally pivoting warning gates and post mounted traffic signals located along the roadway approaching the bridge in approximately the same location as the existing signals and warning gates. A crash tested horizontally pivoting barrier gate will be provided on the bridge, east of the navigation channel, to protect the drop off hazard created when the bascule leaf is raised.

3.2.7 Bridge Hydraulics

The Mitchell River is a 1.1 mile long tidal waterway linking Mill Pond with Stage Harbor and has a Mean Low Water (MLW) Elev. -2.25 feet and Mean High Water (MHW) Elev. +1.50 feet (referenced to NAVD 88.) This crossing site is located in a National Flood Insurance Program (NFIP) coastal flood hazard zone A8. This flood hazard zone designation indicates that the affected lands are subject to flooding during 100-year tidal storm events (Elev. +9.2), but are not expected to be affected by wave action accompanying such storms. The local 10-year, 50-year and 100-year Tidal Flood elevations are Elev. +4.5, +7.6, and +9.2 feet. None of the replacement bridge alternatives introduce an adverse impact on the tidal flow and maximum waterway velocities will not introduce significant degradation of the river channel bed profile.

3.2.8 Construction Traffic Management

As the bridge will be replaced on the same alignment as the existing bridge, a single traffic management stage will be used during demolition and construction by closing the bridge and detouring traffic using the local road system including Stage Harbor Road, Main Street and Bridge Street. There will also be short duration periods where the navigation channel will be closed to navigation traffic. Winter flounder spawning in the waters of Stage Harbor will restrict in-water construction and silt producing activities from January 15 through May 31, which will extend the overall duration of construction.

3.2.9 Geotechnical

The subsurface profile of the riverbed typically consists of an 8 to 12 feet layer of loose/soft organic material, followed by a 15 to 20 feet layer of fine sand and clay, followed by a 15 feet layer of medium dense sand, on top of a very dense sandy glacial till material located approximately 38 to 47 feet below the river bed. Because of the loose/soft organic upper layers, driven pile foundations are required to support the replacement bridge. The bearing capacity will be achieved from frictional resistance through the sand, silt, and clay layers and some end bearing capacity in the dense sandy glacial till.

3.2.10 Environment

The Stage Harbor System consists of six embayments: Stage Harbor, Oyster Pond River, Oyster Pond, Mitchell River, Mill Pond, and Little Mill Pond. The system provides safe anchorage for local recreational and commercial fishing boat uses with numerous moorings north and south of the bridge and is an important marine resource.

The Massachusetts Division of Marine Fisheries has identified the waters of Stage Harbor and surrounding embayments as winter flounder (a commercially important finfish species) spawning habitat and as such, a time-of-year prohibition from January 15 through May 31 will be in place for all in-water construction and any silt producing activities.

The Massachusetts Division of Fisheries and Wildlife has indicated the following state-listed rare species have been found in the vicinity of the site: roseate tern, common tern, arctic tern, and least tern.

This segment of the Mitchell River is known for its high quality of quahog shellfishery and likely provides excellent habitat for additional shellfish species including soft-shell clams, oysters, scallops and mussels. The Massachusetts Division of Marine Fisheries lists this area as an "approved" shellfish growing area.

According to the Department of Environmental Protection Eelgrass Mapping Project, eelgrass was documented immediately south of the bridge in 1995. Although subsequent mapping in 2001 did not record eelgrass in the immediate vicinity of the bridge, requirements will be in place to avoid eelgrass beds with new construction.

On the east side of the bridge, salt marsh extends up from the bank of the river to upland forest and an isolated vegetated wetland is located in the southeast quadrant of the bridge. The west side of the bridge is heavily developed in the southwest quadrant, leaving no jurisdictional wetlands in the vicinity of the bridge. However, a section of salt marsh was delineated in the northwest quadrant between the abutment and the boat launch.

The existing timber piles and other submerged timber elements (e.g. bracing members and fender system) contain creosote wood preservatives. Submerged timber with creosote timber preservatives are known to leech polycyclic aromatic hydrocarbons (PAHs), which are known carcinogens, into the water. These substances are known to be toxic to aquatic organisms and are known to accumulate in the sediments immediately adjacent to the bridge. Construction operations including removal of existing piles and excavation for new foundations will create turbidity and disturb these sediments. Turbidity control will be required during pile removal operations including use of floating silt curtains around the piles. In addition, excavated material for new foundations will be required to be contained within steel sheet pile cofferdams, collected and removed offsite.

Other timber elements (e.g. cap beams, stringers, deck, railings and curbs) contain timber preservatives such as ammoniacal copper zinc arsenate (ACZA) or chromated copper arsenate (CCA), both of which are considered hazardous substances. The existing hazardous timber material will be removed offsite and disposed in accordance with applicable local, state and federal regulations.

3.3 Alternative Descriptions

With consideration of the above criteria, the following five (5) viable bridge replacement alternatives were developed, evaluated and compared:

Alternative 1: Timber Superstructure on Timber Substructure with Timber Bascule Span
Alternative 2: Timber Superstructure on Timber Substructure with Steel Bascule Leaf on Concrete Bascule Pier
Alternative 3: Timber Superstructure on Concrete and Steel Substructure with Steel Bascule Leaf on Concrete Bascule Pier
Alternative 4: Timber Deck and Steel Stringer Superstructure on Concrete and Steel Substructure with Steel Bascule Leaf on Concrete Bascule Pier
Alternative 5: Concrete Deck and Beam Superstructure on Concrete and Steel Substructure with Steel Bascule Leaf on Concrete Bascule Pier

As Bridge Rehabilitation is nearly the same as Alternative 1, there is no need to evaluate this alternative separately and the same results and conclusions can be drawn for this alternative as with Alternative 1.

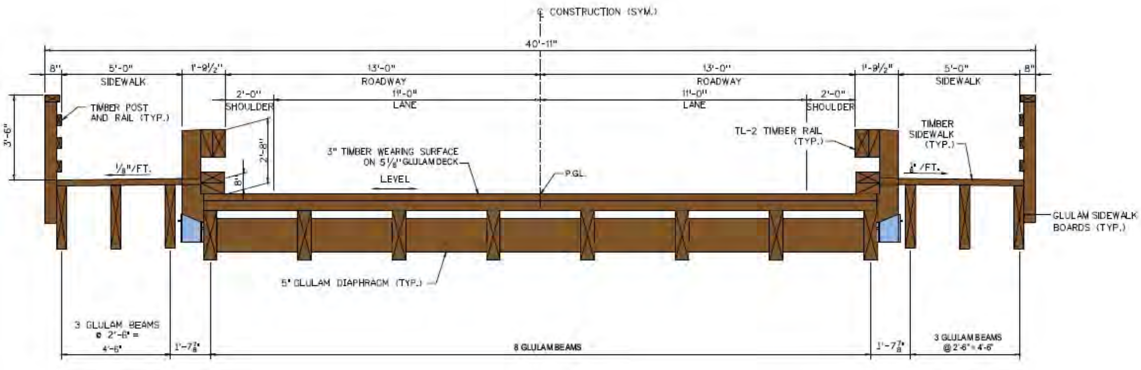
3.3.1 Alternative 1 - Timber Superstructure on Timber Substructure with Timber Bascule Span

This alternative generally consists of an all timber superstructure (i.e. timber wearing surface, structural deck, beams, diaphragms, traffic railings, pedestrian railings, and lifting beam) supported on an all timber substructure (i.e. timber piles, bent caps, bracing, sheave poles, and fender system) that closely resembles the existing bridge, but is modified to include improvements.

This alternative consists of a 192'-0" long twelve-span bridge with a single-leaf bascule span over a navigation channel matching the location and width of the existing channel. The span arrangement is similar to the existing bridge and consists of six (6) 16'-0" west approach spans, a 10'-0" flanking span (i.e. span over the counterweight immediately west of the bascule span), a 22'-0" bascule span, and four (4) 16'-0" east approach spans, measured from center of pile bents or face of abutment back walls. (See Existing Bridge Plans in Appendix A.)

The proposed superstructure includes a sawn lumber plank timber wearing surface with the planks oriented parallel to the roadway centerline and which extends the width of the roadway. The timber wearing surface is supported on and nailed to sawn lumber plank timber structural deck with the planks oriented perpendicular to the roadway centerline and that extends the full width of the bridge. The timber structural deck is supported on sawn lumber stringers. Crash tested timber traffic railings, meeting AASHTO and NCHRP 350 requirements and consisting of glue laminated timber rail elements and sawn lumber posts and curbs, separate the roadway from the sidewalk. The timber bridge railing consists of sawn lumber rails, posts and curbs with the potential to implement components from the existing timber bridge railing. The timber material is Douglas Fir

Larch or Southern Yellow Pine, pressure treated per the American Wood Protection Association (AWPA) or untreated tropical timber.



ALTERNATIVE 1 - SECTION THRU APPROACH AND BASCULE SPANS

The proposed substructure over the waterway consists of pile bents with timber piles, sawn lumber caps and sawn lumber lateral and longitudinal timber bracing members. The timber material is Douglas Fir Larch or Southern Yellow Pine, pressure treated per AWPA or untreated tropical timber. The substructure at the ends of the bridge consists of pile supported concrete abutments. The abutments include integral concrete wing walls (retaining walls) that extend along the approach roadway at the back of sidewalk that retain the roadway embankment. The retaining walls extend beyond the bridge ends approximately 90 feet at the NW quadrant, 20 feet at the SW quadrant, 20 feet at the NE quadrant and 60 feet at the SE quadrant. The embankments adjacent to the abutments and retaining walls along the waterway contain rubble rip rap slope protection.

The proposed bascule span channel provides 19’-4” of horizontal width between fenders, approximately 7’-4” of vertical clearance above mean high water with the bascule leaf in the lowered position and unlimited vertical clearance with the bascule leaf fully raised. The pivot for the bascule leaf is located on the west side of the navigation channel. The bascule leaf is approximately 24’-6” from pivot to tip and rotates to a maximum angle of approximately 82.5 degrees and fully clears the fender with the bascule leaf fully raised. In order to reduce the loads on the operating machinery, the bascule leaf is balanced by a 7’-6” long counterweight with stainless steel plate bolted to the underside of the timber stringers that fully clears the water at high tide with the bascule leaf fully raised.

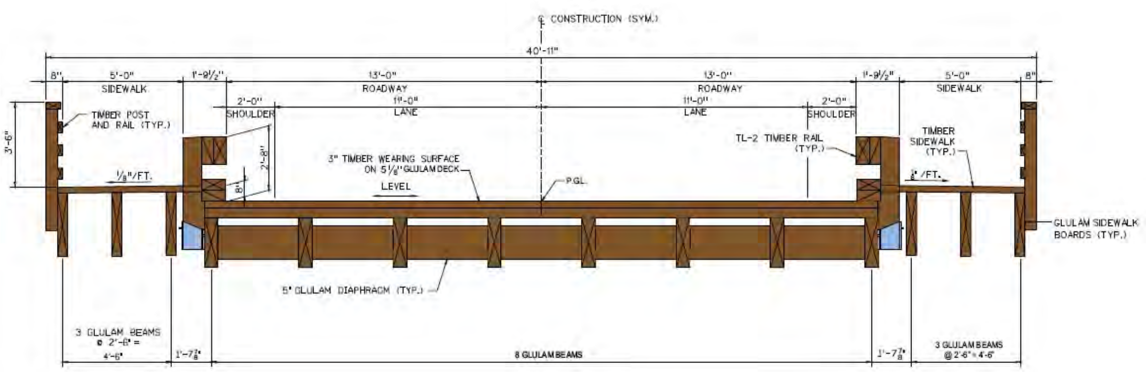
The timber stringers for the bascule leaf are located in between the timber stringers of the flanking span. The bascule leaf superstructure pivots about a steel rod that passes through steel pipe sleeves through each of the bascule leaf and flanking span timber stringers. A manually operated hinged deck flap above the pivot provides clearance between the timber stringers and deck when the bridge operates.

The fender system consists of a combination of horizontal and vertical timber members attached to the timber pile bents each side of the navigation channel.

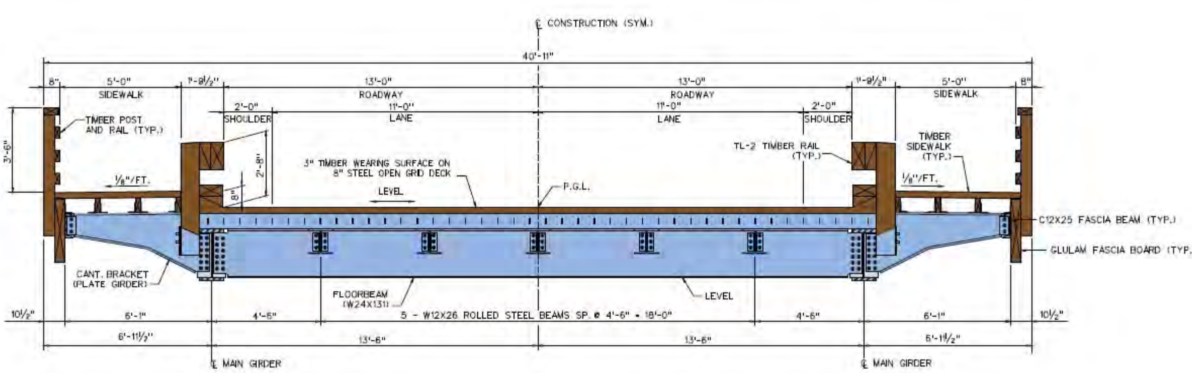
The proposed bascule span is operated by a pair of electric winches, located outboard each sidewalk, so as to not impair accessibility, on the approach spans west of the bascule span. Each winch draws in and pays out wire operating rope attached to a pulley system for additional mechanical advantage. The pulley system is attached to wire rope attached to the ends of a lifting beam under the bascule leaf deck near the tip ends of the leaf that deflects over a deflector sheave located at the top of a sheave pole. Each sheave pole consists of a timber mast with guy wire attached near the top of the mast and to the bridge superstructure. The wire rope, pulleys and deflector sheaves are designed to meet AASHTO requirements and will be significantly larger than the same elements of the existing bridge (e.g. the deflector sheave will be 45” in diameter compared to the existing 15”.) An electrical control cabinet is located within a timber shed located outboard the sidewalk and with an architectural style matching adjacent buildings.

3.3.2 Alternative 2 - Timber Superstructure on Timber Substructure with Steel Bascule Leaf on Concrete Bascule Pier

This alternative generally consists of an all timber approach span superstructure (i.e. timber wearing surface, structural deck, beams, diaphragms, traffic railings, pedestrian railings, and lifting beam) supported on an all timber substructure (i.e. timber piles and bent caps) that closely resembles the approach spans on the existing bridge, but is modified to include improvements. The bascule span superstructure generally consists of a timber roadway deck and sidewalks on steel framing supported on concrete bascule pier substructure.



ALTERNATIVES 2 AND 3 - SECTION THRU APPROACH SPANS



ALTERNATIVES 2 AND 3 - SECTION THRU BASCULE SPAN

This alternative consists of a 193’-3” long ten-span bridge with a single-leaf bascule span over a wider navigation channel than the existing channel. The span arrangement is similar to the existing bridge, but modified for the bascule span, and consists of five (5) 16’-0” west approach spans, a 49’-3” bascule span including bascule pier and bascule leaves, and four (4) 16’-0” east approach spans, measured from center of pile bents or face of abutment back walls. (See Existing Bridge Plans in Appendix A for Approach Spans and Alternative 3 below for Bascule Span.)

The proposed approach superstructure includes a sawn lumber plank timber wearing surface with the planks oriented parallel to the roadway centerline and which extends the width of the roadway. The timber wearing surface is supported on and nailed to sawn lumber plank timber structural deck with the planks oriented perpendicular to the roadway centerline and that extends the width of the roadway. The timber structural deck is supported on glue laminated timber stringers. The sidewalk consists of sawn lumber planking oriented perpendicular to the roadway centerline and supported on glue laminated timber stringers. Crash tested timber traffic railings, meeting AASHTO and NCHRP 350 requirements and consisting of glue laminated timber rail elements and sawn lumber posts and curbs, separate the roadway from the sidewalk. The timber bridge railing consists of sawn lumber rails, posts and curbs with the potential to implement components from the existing timber bridge railing. The timber material is Douglas Fir Larch or Southern Yellow Pine, pressure treated per AWPA or untreated tropical timber.

The proposed approach substructure over the waterway consists of pile bents with timber piles, sawn lumber caps and sawn lumber lateral and longitudinal timber bracing members. The timber material is Douglas Fir Larch or Southern Yellow Pine, pressure treated per AWPA, or untreated tropical timber. The substructure at the ends of the bridge consists of pile supported concrete abutments. The abutments include integral concrete wing walls (retaining walls) that extend along the approach roadway at the back of sidewalk that retain the roadway embankment. The retaining walls extend beyond the bridge ends approximately 90 feet at the NW quadrant, 20 feet at the SW quadrant, 20 feet at the NE quadrant and 60 feet at the SE quadrant. The embankments adjacent to the abutments and retaining walls along the waterway contain rubble rip rap slope protection.

The proposed bascule span channel provides 25’-0” of horizontal width between fenders, approximately 7’-4” of vertical clearance above mean high water with the bascule leaf in the lowered position and unlimited vertical clearance with the bascule leaf fully raised. The pivot for the bascule leaf is located on the west side of the navigation channel. The bascule leaf is approximately 33’-9” from pivot to tip and rotates to a maximum angle of approximately 80.0 degrees and fully clears the fender with the bascule leaf fully raised. In order to reduce the loads on the operating machinery, the bascule leaf is balanced by a 12’-6” long counterweight with a steel counterweight box filled with concrete and steel ballast.

The roadway cross section on the bascule leaf matches that of the approach spans. The bascule leaf superstructure consists of a sawn lumber plank timber wearing surface with the planks oriented parallel to the roadway centerline and which extend the width of the roadway. The timber wearing surface is supported on and bolted to steel open grid flooring panels that span perpendicular to the roadway centerline. The steel framing includes two variable depth main girders, floorbeams, floorbeam cantilevered brackets, and stringers. The floor system is braced with horizontal diagonal bracing members. The steel counterweight box frames between the main girders at the tail end of the bascule leaf. The bascule leaf includes a timber sidewalk and pedestrian railing similar to that of the approach span including timber fascia boards that hide the steel and concrete bascule leaf superstructure. The bascule leaf is supported on and pivots about a steel tube member between the main girders that includes a pair of trunnion shafts.

The proposed bascule leaf is supported on a reinforced concrete bascule pier that includes concrete walls that fully enclose the pier, pedestals that support the operating machinery, platforms for maintenance access to the equipment, and a footing embedded in the river bed. The bascule pier is constructed using a steel sheet pile cofferdam to permit the footing and walls below water to be constructed in the dry. The bascule pier is supported on concrete filled driven steel pipe piles. The bascule pier deck consists of a sawn lumber plank timber wearing surface with the planks oriented parallel to the roadway centerline and which extend the width of the roadway. The timber wearing surface is supported on and nailed to a glue laminated timber structural deck that spans parallel to the roadway centerline between the back and front walls of the pier. The bascule pier deck includes slots at the main girders and traffic railing in order to provide operational clearances for the pivoting bascule leaf. Floor hatches with vertical access ladders provide access into the piers. The exterior faces of the bascule pier will include stone facing using materials and details consistent with the local community. The concrete bascule pier will introduce local pier scour of approximately 12 feet compared to the 4 feet of local pier scour at the approach pile bents. The tip end of the bascule leaf rests on an approach pile bent (i.e. rest bent) with the leaf in the lowered position.

The fender system each side of the navigation channel consists of a combination of horizontal and vertical timber members attached to the face of the concrete bascule pier and rest bent concrete filled steel pipe piles.

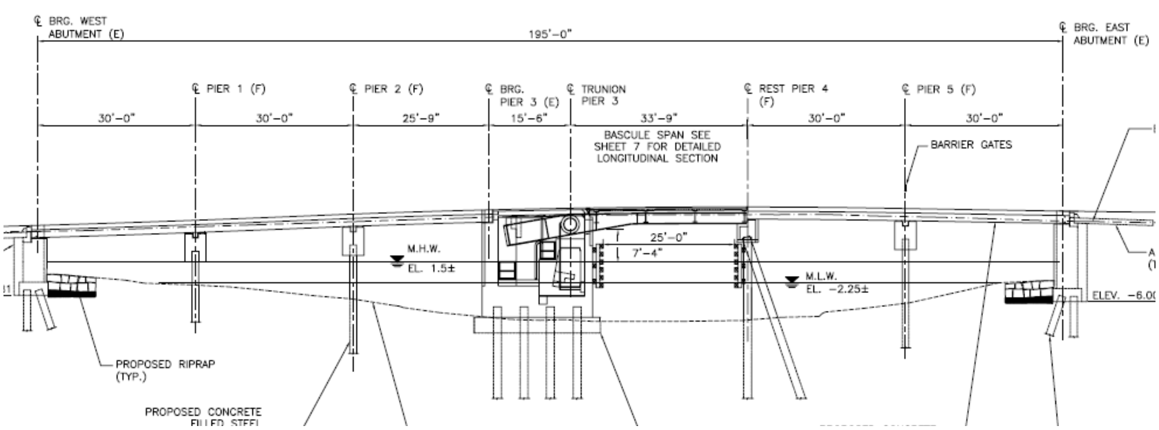
The drive machinery consists of two independent drive trains each directly coupled to the outboard end of the trunnion shafts. Each independent drive train consists of an electric motor, thruster type brake, motor coupling, right-angle reducer, flex coupling, planetary reducer and gear coupling. All gear reduction is provided by enclosed speed reducers (i.e. no open gearing) which reduces maintenance and improves safety. A means to manually operate the bridge is integrated into the drive train in the event of a complete loss of power to the motors. A locking device is provided at the tip end of the bascule leaf to prevent inadvertent uplift of the bascule leaf.

A relay based control system with safety interlocks and permissives will be used for bridge operation. The bridge is operated from a control console located on the bascule pier deck adjacent to the channel for maximum visibility of the waterway and roadway with the leaf both raised and lowered. The electrical equipment will be located in a small at the bascule pier deck above the 100-year flood elevation in a shed. The shed will have an architectural style matching buildings adjacent to the bridge. Electrical power and controls for the navigation lighting, warning gates, barrier gate(s), traffic signal and span locks on the opposite side of the navigation channel will be provided by way of a subaqueous cable installed in a backfilled trench across the channel.

3.3.3 Alternative 3 - Timber Superstructure on Concrete and Steel Substructure with Steel Bascule Leaf on Concrete Bascule Pier

The proposed approach spans for this alternative generally consist of an all timber superstructure (i.e. timber wearing surface, structural deck, beams, diaphragms, sidewalks, traffic railings, and pedestrian railings) supported on pile bent substructure units constructed with steel piles and concrete caps. The bascule span superstructure generally consists of a timber roadway deck and sidewalks on steel framing supported on concrete bascule pier substructure.

This alternative consists of a 195'-0" long six-span bridge with a single-leaf bascule span over a wider navigation channel than the existing channel. The span arrangement consists of two (2) 30'-0" west approach spans, a 25'-9" flanking span (immediately west of the bascule span), a 49'-3" bascule span including bascule pier and bascule leaves, and two (2) 30'-0" east approach spans, measured from center of pile bents or face of bascule pier or abutment back walls.



ALTERNATIVES 3, 4 AND 5 - BRIDGE LONGITUDINAL SECTION

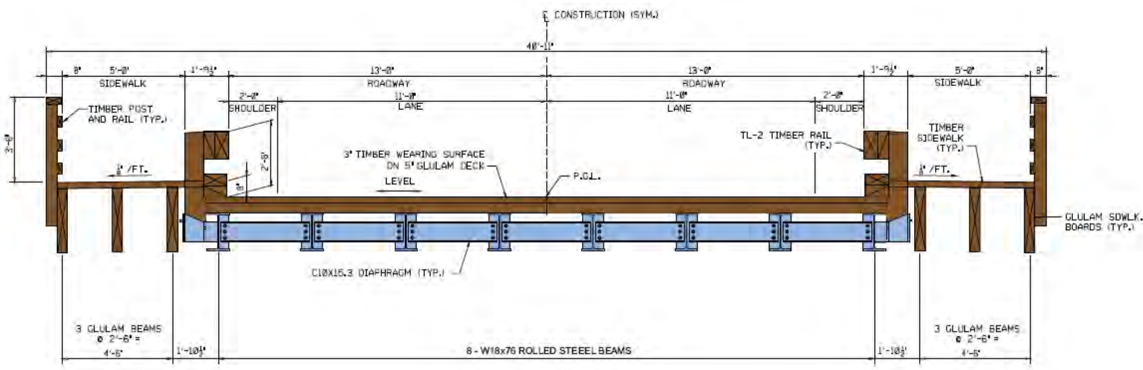
The proposed approach superstructure includes a sawn lumber plank timber wearing surface with the planks oriented parallel to the roadway centerline and which extends the width of the roadway. The timber wearing surface is supported on and nailed to sawn lumber plank timber structural deck with the planks oriented perpendicular to the roadway centerline and that extends the width of the roadway. The timber structural deck is supported on glue laminated timber stringers. The sidewalk consists of sawn lumber planking oriented perpendicular to the roadway centerline and supported on glue laminated timber stringers. Crash tested timber traffic railings, meeting AASHTO and NCHRP 350 requirements and consisting of glue laminated timber rail elements and sawn lumber posts and curbs, separate the roadway from the sidewalk. The timber bridge railing consists of sawn lumber rails, posts and curbs with the potential to implement components from the existing timber bridge railing. The timber material is Douglas Fir Larch or Southern Yellow Pine, pressure treated per AWPA, or untreated tropical timber.

The proposed substructure over the waterway consists of pile bents with concrete-filled, driven steel pipe piles, and reinforced concrete caps. The substructure at the ends of the bridge consists of pile supported concrete abutments. The abutments include integral concrete wing walls (retaining walls) that extend along the approach roadway at the back of sidewalk that retain the roadway embankment. The retaining walls extend beyond the bridge ends approximately 90 feet at the NW quadrant, 20 feet at the SW quadrant, 20 feet at the NE quadrant and 60 feet at the SE quadrant. The embankments adjacent to the abutments and retaining walls along the waterway contain rubble rip rap slope protection.

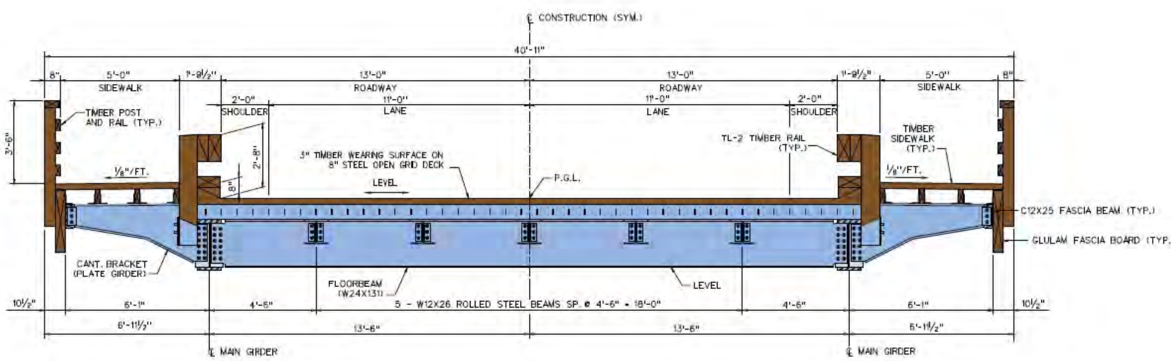
The proposed bascule span arrangement and details including the fender system are the same as that for Alternative 2.

3.2.4 Alternative 4 - Timber Deck and Steel Stringer Superstructure on Concrete and Steel Substructure with Steel Bascule Leaf on Concrete Bascule Pier

The bridge length, span arrangement and details including the fender system for this alternative are generally the same as that for Alternative 3 with the exception that the approach span timber deck (i.e. timber wearing surface, structural deck, sidewalks, traffic railings, and pedestrian railings) is supported on steel stringers and diaphragms instead of timber beams and diaphragms and the timber sidewalk beams hide the steel beams.



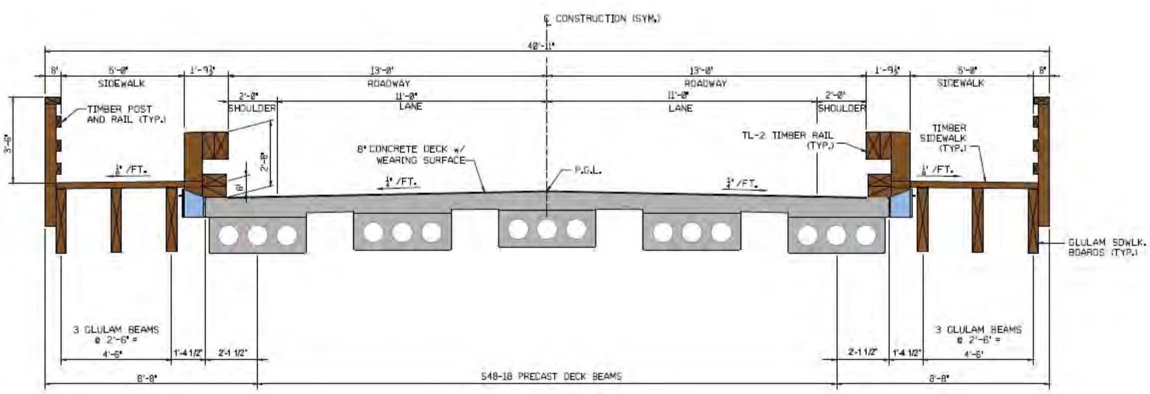
ALTERNATIVE 4 - SECTION THRU APPROACH SPANS



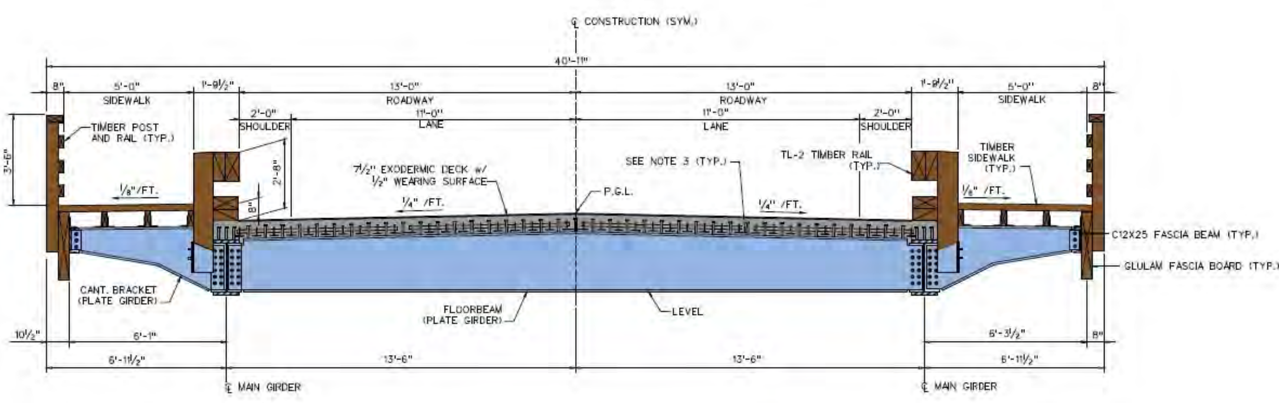
ALTERNATIVE 4 – SECTION THRU BASCULE SPAN

3.3.5 Alternative 5 - Concrete Deck and Beam Superstructure on Concrete and Steel Substructure with Steel Bascule Leaf on Concrete Bascule Pier

The bridge length, span arrangement and details for this alternative are generally the same as that for Alternatives 3 and 4 with the exception that the approach span superstructure consists of a concrete roadway deck for the width of the roadway supported on prestressed concrete deck beams. The sidewalks, traffic railings, and pedestrian railings for the approach spans are timber similar to the other alternatives. The bascule span is also similar to Alternatives 3 and 4 with the exception that the bascule leaf superstructure consists of a concrete deck for the width of the roadway supported on steel framing. The sidewalks, traffic railings, and pedestrian railings on the bascule span including bascule leaf and bascule pier are timber similar to the other alternatives and the timber fascia boards hide the steel framing. The concrete roadway deck throughout the bridge has a stamped concrete pattern and color admixtures that simulate timber.



ALTERNATIVE 5 - SECTION THRU APPROACH SPANS



ALTERNATIVE 5 – SECTION THRU BASCULE SPAN

3.4 Construction Materials

3.4.1 General

As the existing bridge was determined to be NRHP eligible on the basis that it is one of the last remaining single-leaf timber drawbridges, timber is considered in the replacement bridge to the maximum extent feasible and prudent to mitigate replacement of the NHRP eligible bridge. Timber is a relatively low cost material and thus can yield a cost effective solution and thus is evaluated and compared with other materials such as concrete and steel for various elements of the bridge. However, timber has a number of limitations that introduce challenges in meeting certain project design criteria and that make it not the best material for certain applications. As such, timber may not be the most prudent construction material for use in all elements of the bridge and other construction materials may better meet certain project design criteria.

3.4.2 Component Evaluation

Miscellaneous Members: Timber is a viable material for the sidewalks, traffic railing, and pedestrian railings. Timber sidewalks, traffic railings and pedestrians railings provide a context sensitive solution and can meet all required functional and safety criteria. Although timber has a shorter service life than concrete and steel and thus requires greater maintenance, the relatively low cost of timber, and the ability to replace these members independently on a piecemeal basis, with minimal disruption to the public, makes timber a good candidate for use in these members. As such, timber is recommended for use in the sidewalks, traffic railing and pedestrian railings for Alternatives 1 thru 5.

Deck: Timber is a viable material for the wearing surface and structural deck. A timber deck provides a context sensitive solution and can meet all required functional and safety criteria. A timber deck can provide “traffic calming” and can act to reduce traffic speeds when the deck surface has worn and introduces a rougher ride. However, a new timber deck with planks oriented parallel to the roadway centerline, as recommended, is likely to initially provide a smooth riding surface.

Due to the shorter service life of timber, the need to periodically replace the wearing surface and structural deck, and corresponding disruptions to the traveling public, timber may not be the best construction material for the deck. A timber wearing surface has a relatively short service life as the deck surface can wear rapidly due to abrasion from tire contact and the timber can deteriorate more rapidly due to the severe exposure conditions and greater potential for retained moisture. A timber deck cannot be plowed to remove snow due to the potential to damage the timber surface.

The timber structural deck has a longer service life than the timber wearing surface due to the protection provided by the wearing surface. However, because of several factors including retained moisture between the wearing surface and structural deck, open holes from missing fasteners, etc. the timber structural deck is susceptible to decay and thus has a shorter service life than other materials. Although the timber wearing surface can be replaced independently, the timber structural deck must be replaced in conjunction with the wearing surface. Because of the difference in service life of the wearing surface and structural deck, the wearing surface or structural deck may need to be replaced when it is not otherwise necessary to replace the other element.

Although a concrete deck is more expensive than a timber deck, it has significantly greater service life than a timber deck. However, a concrete deck is not completely maintenance free as the deck surface can periodically become damaged from snow plowing and/or deteriorated from de-icing salts and as such, must be periodically resurfaced. A stamped concrete pattern and color admixtures can be added to the concrete deck to provide the appearance of timber, while also providing a longer lasting, lower maintenance solution.

As there are advantages and disadvantages to both materials, alternatives with timber deck (Alternatives 1 thru 4) and concrete deck (Alternative 5) are evaluated and compared.

Approach Span Superstructure Main Load Carrying Members: Timber is a viable material for the main load carrying members (i.e. stringers) of the short span trestle structure proposed for the approach spans. Sawn lumber beams can be used for the stringers for shorter span lengths (i.e. spans up to about 25’-0”) including the 16’-0” spans proposed for the timber approach superstructure of Alternatives 1 and 2. Glue laminated timber beams must be used for longer span lengths including the 30’-0” spans proposed for the timber superstructure of Alternative 3. Timber stringers provide a context sensitive design and can meet all required functional and safety criteria. Timber stringers have a lower cost but have a shorter service life than steel stringers or concrete beams, as the timber stringers will eventually deteriorate as a result of decay.

Steel stringers and concrete beams have a longer service life than timber stringers, but are not completely maintenance free. Steel stringers require periodically cleaning and painting and repair including strengthening due to corrosive deterioration or fatigue. Concrete beams require patching of cracks and spalls caused by corrosive expansion of the reinforcing steel and freeze-thaw. The timber sidewalk obscures the steel stringers and concrete beams and thus these members are not readily visible.

As there are advantages and disadvantages to all three materials, alternatives with timber stringers (Alternatives 1, 2 and 3), steel stringers (Alternative 4) and concrete beams (Alternative 5) are evaluated and compared.

Bascule Span Superstructure Main Load Carrying Members: Timber is a viable material for the main load carrying members (i.e. stringers) of the bascule span. Timber provides a context sensitive solution for the bascule span and can meet all required functional and safety criteria. However, due to limitations of the strength of both sawn lumber and glue laminated timber, timber main load carrying members lack adequate strength for the bascule leaf to span the navigation opening as a cantilever, and require support at the tip of the bascule leaf during operation. With the support at the tip, the main load carrying members are not cantilevered, but instead are simply supported between pivot and tip, which results in smaller forces in the members. This is the case with the existing bridge, where the tip of the bascule leaf is supported by operating cables attached to a lifting beam under the deck near the tip. (Note: This is also the case on numerous timber bascule span designs found in Europe that utilize an overhead counterweight, where the tip of the bascule leaf is supported by link arms attached to the overhead frame that supports the counterweight.) The significantly larger size of timber main load carrying members to span the navigation channel as a cantilever would result in the members encroaching on the existing vertical understructure clearance or would result in the members extending above the deck. Members extending above the deck are not recommended as this would require a wider bridge to accommodate the additional width of these members above the deck. As such, a timber bascule span cannot be configured in a cantilever configuration, similar to most typical steel bascule span designs, and thus a completely different configuration with the bascule leaf supported at the tip, similar to the existing bridge, must be used for an all timber bascule span.

Because the timber bascule leaf lacks the strength to cantilever from the pivot and requires support at the tip of the leaf during operation, the operating and support system is limited to the same type used in the existing bridge. The cable operating system is generally less desirable for several reasons including:

- Higher maintenance with frequent cleaning and lubrication of the operating ropes
- Lower durability with frequent replacement of the wire ropes due to fatigue and wear
- Relatively shorter service life compared to other types of operating equipment
- Direct exposure to the weather including saltwater, snow and ice, which increases maintenance, promotes deterioration, and reduces reliability
- Equipment location above the deck where it is accessible to unauthorized personnel with public safety concerns and risk of vandalism
- Lack of redundancy (Note: The bascule leaf is inoperable with one of the winches and/or operating cable systems out of service. The bascule span timber framing lacks the lateral strength and stiffness required to permit the span to be supported from one side only. Failure of one of the operating ropes during operation could result in the catastrophic collapse of the bascule span.)

The use of steel framing for the bascule span yields a longer service life and requires less maintenance than timber framing. The timber sidewalk obscures the steel framing and thus these members are not readily visible with the bascule leaf in the lowered position. In addition, steel framing that cantilevers from the pivot permits the use of more desirable direct drive operating equipment, such as that proposed in Alternatives 2 thru 5, located below deck in a full enclosed bascule pier. Direct drive operating equipment offers significant advantages in lower maintenance, greater durability, longer service life, reduced exposure, improved safety, greater reliability, and redundancy, than a cable operated system.

Approach Span Substructure: Timber is a viable material for the short span trestle approach span pile bents. Timber pile bents provide a context sensitive solution and can meet all required functional and safety criteria. The smaller size and shorter available lengths of typical timber piles (12" diameter x 60 feet long) limits the foundation capacity relative to larger concrete and steel piles and thus requires a greater number of timber piles to equal the capacity of larger concrete and steel piles. The limited foundation capacity of timber piles also limits the span lengths and thus shorter span lengths and a greater number of pile bents are required when timber piles are used. The smaller section and lower modulus of elasticity of timber piles yields a significantly more flexible pile bent, and thus requires lateral bracing. Historically, the short service life of timber elements submerged in saltwater (e.g. piles, bracing and fender elements) requires that the timber pile bents be replaced more frequently than piles bents constructed from concrete and steel. As the pile bents support the superstructure, replacement of the pile bents also requires that the superstructure be replaced, even if the superstructure elements have remaining service life, (i.e., replacement of the piles governs the need to completely replace the bridge.) Pile bents constructed with steel piles and concrete caps with no lateral bracing offer significantly greater service life and reduced maintenance compared to timber pile bents.

Alternatives with timber piles introduce greater environmental impacts than alternatives with concrete and steel piles. Each time the piles are replaced, construction operations create turbidity that disturbs the existing waterway bottom sediments. As the sediments below and adjacent to the bridge contain accumulations of PAHs and other toxic substances that have leeched from the existing submerged timber elements, disturbance of these sediments creates conditions potentially harmful to aquatic life. Because of the greater number of timber piles and the need to replace them more frequently than concrete and steel piles, a greater amount of the bottom surface sediments are disturbed more often. New timber piles with preservative treatments potentially leech additional toxic substances into the water. Although the use of "best management practices" can reduce the amount of leeching, these practices are not completely effective. Although use of untreated tropical timber eliminates the leeching of harmful substances into the water, the limited service life of untreated tropical timber requires more frequent replacement that disturbs the existing sediments. The use of concrete and steel piles, in lieu of timber piles, will decrease the disturbance of the contaminated waterway bottom sediments and will avoid deposition of additional toxic substances into the aquatic environment, and thus minimize impacts to the environment.

Bascule Span Substructure: Timber is a viable material to support an all timber bascule span, with a pile bent configuration similar to the existing bridge. This yields a context sensitive solution and can meet all required functional and safety criteria. However, a pile bent configuration is not practical to support the operating equipment below deck and will not protect the operating equipment from direct exposure to the elements or prevent unauthorized access to the operating equipment. Furthermore, a pile bent configuration will not permit the use of a longer counterweight required to balance a longer bascule leaf, as a longer counterweight will become submerged as the bascule leaf operates. A submerged counterweight results in undesirable increases in the loads on the operating equipment as the counterweight becomes buoyant and results in maintenance concerns due to corrosion of steel elements submerged in saltwater. A shorter bascule leaf will not address the current undesirable navigation function and safety conditions.

A concrete bascule pier with footing, walls and deck can fully enclose the counterweight and operating equipment and thus provide a longer lasting solution that requires significantly less maintenance. A fully enclosed pier will permit the counterweight to pivot without becoming submerged and better protect the operating equipment from exposure to the elements and unauthorized access. A concrete bascule pier can include stone cladding and timber roadway deck, sidewalks and railings similar to the approach spans and bascule leaf.

3.4.3 Additional Timber Service Life and Maintenance Considerations

General: Experience with timber in marine environments throughout the United States has consistently demonstrated that timber has a relatively short service life in these conditions compared to other materials such as concrete and steel. Although there have been a number of successful strategies and technologies implemented over the years to extend the service life of timber in other environments, there have been no fully effective solutions to extend the service life of timber in the marine environment that produce consistent results and that do not have other significant consequences. The anticipated minimum service life of each timber element can vary significantly depending on a number of factors including: use; exposure conditions; type and quality of timber, preservative treatments, design details, construction, inspection, and maintenance. Based on experience with timber on bridges in Massachusetts in similar environments, the anticipated service life of the various timber elements are as follows:

Timber Element	Anticipated Overall Service Life (years)		Anticipated Governing Failure Mode(s)
	Worst Case	Best Case	
Wearing Surface	10	20	Wear/Decay
Structural Deck	30	40	Decay
Traffic Railing/Curbs	40	50	Decay
Pedestrian Railings	40	50	Decay
Sidewalk Deck	40	50	Decay
Sidewalk Beams	40	50	Decay
Stringers/Diaphragms	40	50	Decay
Cap Beams	40	50	Decay
Bracing	20	30	Marine Borers/Decay
Piles	20	30	Marine Borers/Decay
Sheave Poles	40	50	Decay
Lifting Beam	40	50	Decay/Fatigue
Fenders	20	30	Marine Borers/Decay
Timber preservative treatments are based on AWPA Guidelines. Service life of timber piles is based on the use of CCA treated Southern Yellow Pine, ACZA treated Douglas Fir, or untreated tropical timber. Further use of creosote treated timber piles is not recommended for this project due to the sensitive and important aquatic environment.			

Decay of timber members occurs where preservative treatments no longer effectively protect the wood, and where moisture, fungi, and bacteria that cause decay enter the wood. Preservative treatments often do not fully penetrate the full cross section of the timber and over time the preservative treatment can leech from the timber, leaving areas of the timber unprotected. Moisture and fungal spores and bacteria can enter the timber and gain access to areas of the timber that are not protected with preservative treatment in a number of ways including through checks and splits, open holes, or through unsealed cut ends. Areas with continuous exposure to moisture such as horizontal surfaces, gaps between components where moisture is retained, and where moisture runs over unsealed cut ends are more conducive to decay. Timber that experiences greater volumetric changes with changes in moisture content is more likely to develop checks and splits. The checks and splits contribute to increased water absorption by providing easier access for moisture to enter grains of the wood, which promotes formation of larger and greater number of checks and splits. Larger checks and splits provide an easier opportunity for fungal spores and bacteria to enter the wood. Volumetric change in the wood also acts to work nails and other fasteners loose, which creates gaps conducive for moisture retention. Corrosive deterioration and removal of nails and other fasteners results in open holes that also provide avenues for moisture to enter the wood. The open exposure of the bridge and the marine environment at this site is conducive for premature deterioration and decay.

Timber Replacement Considerations: The service life of a timber bridge can be extended somewhat by replacing members on a piecemeal basis. A number of the elements can be replaced independently (i.e. they do not require removal of other components for replacement) and as such can be replaced individually as deterioration occurs. Specifically, this includes the wearing surface, traffic railings/curbs, pedestrian railings, bracing, sheave poles, lifting beams and fenders. However, other elements of the bridge cannot be replaced independently as they require removal of other components for replacement. These elements include the structural deck, stringers, cap beams, and piles. In general, it is usually prudent to replace these members when the components that they support are being replaced, even if these members still have some remaining service life.

With an all timber bridge, the overall service life of the bridge is usually dictated by the service life of the piles. Because it is not feasible to replace the piles without complete removal of the remainder of the bridge, the bridge is replaced once the piles reach the end of their service life.

Replacement of sections of larger timber members that cannot be replaced independently (e.g. stringers, cap beams, piles) is generally expensive compared to the cost of replacing the member, due to the high cost of labor and equipment required. However, this solution can be cost effective when there are a small number of members to be repaired and it prevents significant removal and/or replacement of other components. Where a larger number of members must be repaired, it is usually more cost effective to replace the members. Replacement of a section of a timber member includes temporary support and/or jacking of the bridge to remove load from the member, removal of the deteriorated or damaged section by saw cutting, and installation and splicing of the new section to the existing section to remain using timber or steel plates bolted to the pile sections. Replacement of sections of deteriorated timber piles introduces significant additional challenges and cost. As marine borer attack can extend from the portion of pile just above the mudline to just above the tidal zone, much of the pile to be replaced is below water. Replacing a section of pile below water requires specialty personnel, including divers with expertise in underwater construction, and specialty equipment. The cost of this work is much greater than the cost to replace the piles. As with other members, where there are a small number of piles to be repaired, this solution may be cost effective. However, where a larger number of piles must be repaired, it is usually more cost effective to replace the bridge.

Untreated Tropical Timber: Although some untreated tropical timber is considered to have greater resistance to decay and marine borer attack, experience with untreated tropical timber in Massachusetts does not support this claim.

Untreated tropical timber, such as Greenheart and Basralocus, which both have been used in Massachusetts for piles, is generally considered to have greater resistance to decay and marine borer attack. However, according to *Commercial Timbers of the Caribbean (Agriculture Handbook 207)* by the US Department of Agriculture (see Appendix D) "No timber is known to be entirely resistant to marine borers or teredo. A number of Caribbean timbers do exhibit a high resistance to these marine animals. However, the service life of these timbers is often influenced by local conditions and the particular species of marine borers present. Timbers that show high resistance to teredo in Caribbean waters are sometimes far less resistant along the Atlantic Coast of the United States. Similarly, timbers may vary in their resistance between salt and brackish waters. These differences are considered to be the result of different types and species of marine borers from one place to another."

The Powder Point Bridge in Duxbury, Massachusetts (a 2,200-foot long, 133-span timber bridge over the Back River at Duxbury Bay) illustrates this concern (see Appendix D.) The bridge was reconstructed in 1987 using piles made from Basralocus. Although Basralocus reportedly is considered highly resistant to decay, the piles exhibited significant decay and deterioration after only 25 years of use. Based on the referenced statements above and the disappointing performance on the Powder Point Bridge, there are reasons for concern with the use of these materials. Ultimately, there is insufficient evidence to support that tropical timber can be used to significantly increase the service life of the piles at this site.

PHOTO - POWDER POINT BRIDGE - TYPICAL PILE CONDITION

Timber Preservative Treatment: The above referenced article on *Commercial Timbers of the Caribbean*, referring to marine borers, states, “The most practical protection for piling and other timbers used in sea water is heavy treatment with coal-tar creosote or creosote-coal-tar solution.” In addition, the timber preservatives recommended by the American Wood Protection Association (AWPA) for Use Category 5A (UC5A – i.e. wood and wood based materials exposed to salt and brackish water generally from New Jersey and north on the east coast and north of San Francisco on the west coast to the extent that the marine borers can attack) include creosote, ammoniacal copper zinc arsenate (ACZA) and chromated copper arsenate (CCA). However, because of the restricted use and general widespread opposition to use in marine environments in Massachusetts due to environmental and human health concerns, it may not be prudent to use creosote and these other more effective preservative treatments on this project. Proponents of creosote preservative treatments such as the Western Wood Preservative Institute, the Creosote Council, and others argue that the environmental concerns are unfounded and that there is limited risk in using these preservatives in aquatic environments. Until these disagreements can be resolved, the general discouragement on the use of these preservatives is likely to remain and there are risks that timber piles with these preservative treatments may not be permitted. Although there are other timber preservatives that are safe for use in aquatic environments and not restricted in Massachusetts, these preservatives are not recommended by AWPA for UC5A, as they are significantly less effective in resisting marine borer attack and decay. As such, life cycle cost analysis is based on piles with a limited (i.e. 20 to 30 years) service life.

In-place Preservative Treatments: As discussed in the *Bridge Repair/Rehabilitation Feasibility Study*, the use of in-place preservative treatments to extend the service life of the timber components is not prudent. The currently available treatment techniques and chemical preservatives have limited effectiveness and require frequent reapplication (every 5 to 10 years). Some of the treatment would require removal of significant portions of the bridge to provide access for the retreatment. This effort would likely become a significant maintenance burden to the Town in cost, effort and disruption to the traveling public. Furthermore, the currently available effective treatment techniques and chemical preservatives introduce human health and environmental contamination risks, with a potential that this treatment will not be permitted for use in this environment.

Plastic Pile Wraps: Plastic wrapping of piles has had some limited effectiveness in slowing or stopping marine borer attack. However, the plastic wrap obscures the piles from visual inspection and tactile inspection (i.e. sounding and probing) is also not recommended on these piles due to the potential of damaging the plastic wrap. As such, there is no practical means to perform routine inspection of these piles and to periodically determine whether the condition is deteriorating beneath the plastic.

FRP Pile Jackets: The service life of deteriorated timber piles can be extended by strengthening the piles using fiber reinforced polymer (FRP) composite jackets that completely wrap the piles and that are filled with epoxy grout. In addition to restoring the strength of the piles, the jackets prevent decay and marine borer attack by preventing access to fungal spores and marine borers. Although a relatively new technology, the FRP jackets have been used successfully over the last decade on a number of bridge, pier and wharf foundations supported on timber piles. However, as it is a relatively new technology, long-term performance data in the extremely aggressive saltwater environment is not available and thus the predicted service life of the jackets is somewhat unknown. The FRP material and associated adhesives, grout and coatings are potentially susceptible to wear from abrasion, impact damage, delaminations due to freeze-thaw, and degradation due to ultraviolet light and exposure to the salt water. The current cost of FRP jackets is very high (approximately ten times the cost of new piles.) The cost to jacket all of the timber piles is estimated to be of a similar magnitude to the cost of complete replacing the bridge. In consideration of all of the above factors, the use of FRP jackets is not recommended.

3.5 Navigation Opening and Bascule Span Design

A letter from the United States Coast Guard dated February 12, 2010, states "… there have been numerous structural and operational issues involving this bridge over the past several years. A design flaw in the original construction of the bridge prevented it from fully opening for passage of vessel traffic resulting in several mishaps wherein vessels sustained damage to their rigging due to hitting the tip of the draw span. In its present condition the draw span cannot fully open to provide unobstructed vertical clearance for the full width of the bridge between fender faces. The Coast Guard, therefore, will seek to promote the optimum navigational opening for any proposed replacement structure." An increase in the horizontal navigation opening and the limited vertical clearance between the superstructure and the water and introduce challenges to providing an all timber bascule span similar to the existing bridge.

3.5.1 Navigation Opening

The existing bascule span currently provides 19'-4" of horizontal clearance between fenders. The bascule leaf is approximately 23'-8" from pivot to tip and rotates to a maximum angle of approximately 75 degrees from the horizontal position in the fully raised position. With the bascule leaf in the fully raised position, the bascule leaf overhangs the west fender and provides unlimited vertical clearance for a width of only approximately 15'-2" between leaf tip and east fender. As such, navigation through the bridge continues to be a challenge and a safety concern for the boating community. Due to the significant challenges of navigating this narrow opening, boating interests have requested for improvements to the navigation opening and have confirmed that a minimum horizontal clear opening with unlimited vertical clearance for a width of 25'-0" would meet their needs.

Evaluation of the bascule span geometry confirmed, that it is feasible to improve the navigation opening with a single-leaf all timber bascule span, similar in appearance to the existing bridge (Alternative 1.) However, the maximum navigation opening with unlimited vertical clearance that can be achieved is 19'-4". Improvements over the existing bridge design can be accomplished by shifting the pivot point back slightly, rotating the leaf to a steeper opening angle, shifting the sheave pole back, and providing a counterweight fabricated using only stainless steel plate (i.e. no concrete) to prevent the counterweight from dipping in the water. Based on comments received, it appears that a navigation opening width less than 25'-0" will not adequately serve the boating community in the long-term and as a result, the US Coast Guard may be hesitant to permit a bridge with this opening width.

3.5.2 Counterweight

The limited vertical clearance between the superstructure and the water restricts the length of the counterweight and the requested increase in the horizontal navigation opening requires a longer bascule leaf, which requires a longer counterweight to balance the bascule leaf.

This issue is already a concern with the existing bridge, as the counterweight becomes partially submerged in the saltwater as the bascule leaf operates at high tide. This is generally undesirable for two reasons:

1. The effectiveness of the counterweight to balance the operating forces is lessened when it dips in the water and becomes somewhat buoyant, which increases the power required to operate the span and the forces in the operating equipment.
2. Submerging the steel counterweight in saltwater results in corrosion of the steel, which results in loss in section and additional maintenance.

There are several alternative solutions to preventing the counterweight from becoming submerged when the bascule leaf operates:

Shorter Counterweight: For alternatives without a concrete bascule pier that encloses the pivoting counterweight (Alternative 1), a shorter counterweight must be used (approximately a 7'-6" length compared the current 9'-2" length of the existing bridge), which requires a heavier counterweight. The counterweight can be replaced with a new counterweight fabricated using stacks of stainless steel plate (in lieu of a combination of concrete and steel) and stainless steel mounting bolts, which will reduce the maintenance requirements and extend the service life of the counterweight. However, as the geometry limits the length of the counterweight and the amount of counterweight that can be used, there is a limit on the length of the bascule leaf with this solution. Without a concrete bascule pier that fully encloses the pivoting counterweight, the maximum horizontal navigation channel opening with unlimited vertical clearance is 19'-4". (This corresponds to a 24'-6" long bascule leaf from pivot to tip that fully clears the fenders with a bascule leaf fully raised to a maximum opening angle of 82.5 degrees.) This provides a context sensitive solution that closely matches the existing bridge.

(Note: Although a double-leaf bascule span can provide the desired 25'-0" wide navigation opening with unlimited vertical clearance with shorter counterweights that do not become submerged, there are other significant concerns with an all timber double-leaf bascule span. Each bascule leaf would require its own sheave poles, lifting beams, operating winches and wire rope similar to the single-leaf design. Each bascule leaf has the same concerns identified for the all timber single-leaf bascule span (Alternative 1.) In addition, without a pile bent under the tip of the bascule leaf with the leaf in the lowered position, the operating cables will be required to support vehicular loads. This will result in the need for significantly larger operating equipment than required to operate the bascule span and increased wear and fatigue of the operating ropes, sheave poles, and lifting beams. Stability for live load would require a rear anchorage at the tail end of the counterweight, consisting of a large mass of concrete embedded in the waterway bottom, and a pair of span locks at the tip end of the leaves that force the two leaves to deflect together so that continuity of the deck surface is maintained, both of which would introduce design and maintenance concerns. Reattachment of rear anchorage piles to the large mass of concrete in the river bed when the timber bridge is periodically replaced will be a challenge. The large concentrated live loads transferred through the span locks into the timber members will be a significant challenge with the limited understructure clearance and limited strength of timber. Due to these concerns, a double-leaf bascule span is not discussed further.)

Dry Counterweight Pit: Fully enclose the counterweight in a concrete pier with a dry pit that allows the counterweight to pivot below the water surface without becoming submerged and that protects the counterweight from corrosion (Alternatives 2 thru 5.) As there is no practical limitation on the bascule pier dimensions, the length and depth of the bascule pier and length and weight of the counterweight can be optimized to yield the most cost effective solution. This solution can easily accommodate the desired 25'-0" wide minimum horizontal navigation channel opening with unlimited vertical clearance. The concrete bascule pier also better protects the operating equipment from exposure to the weather and the potential for vandalism by locating the equipment within the fully enclosed pier walls. A concrete bascule pier can accommodate use of more durable and reliable direct drive operating equipment when used together with a steel bascule span. The use of stone cladding, and timber railings, sidewalks and bridge deck can be used to provide a context sensitive solution.

Overhead Counterweight: Locate the counterweight above the roadway on an independent counterweight support frame (a.k.a. balance frame) so that the counterweight pivots well above the waterway and does not become submerged during operation. However, the use of an overhead counterweight was previously presented to the community during public meetings, and was generally dismissed as being unacceptable.

3.6 Life Cycle Cost Analysis (LCCA)

3.6.1 LCCA Approach

The financial value of the five (5) bridge replacement alternatives were compared using a life cycle cost analysis (LCCA). LCCA is universally used throughout the United States by transportation agencies as a method to compare the financial value of different competing design alternatives. LCCA consists of an economic assessment of alternatives, considering all significant costs of ownership over the economic life of each alternative, expressed in equivalent dollars (e.g. net present value.) LCCA recognizes, due to the change in the value of money over time, that expenditures at different times in the future have different value. In order to compare the value of different alternatives on an equal financial basis, the cost of expenditures at different times must be equated using the concept of opportunity cost (i.e. the forgone opportunity for an expected rate of return on capital when that capital is used for another purpose.) Opportunity cost considers a combination of rate of return on an investment and inflation and is computed using a discount (interest) rate. MassDOT currently recommends the use of a discount rate from 0.5% to 1.0% to equate future costs to net present value in performing LCCA. A discount rate of 0.8% was used for this study.

Due to a wide variety of factors that contribute to deterioration, it is difficult to estimate with accuracy the service life of various members. However, experience with similar bridges in similar environments in Massachusetts provides some guidance in this area. For each alternative, a sensitivity analysis was performed that considers the “Best Case” (longest) and “Worst Case” (shortest) anticipated service life of each group of similar components. For a detailed summary of the service life assumed for each of the component groups, see Appendix B. This reflects the discussion in Article 3.4.3 above regarding the service life and replacement considerations of timber members. Routine maintenance costs for the bridge are based on the most recent Town of Chatham 5-Year Capital Budget Detail Report.

The time period that the LCCA is performed is typically the total length of time the facility is expected to serve its intended function. However, as the anticipated service life of each of the alternatives for this project varies significantly, the time period used in each analysis is based on a consistent future point in time corresponding to the longest anticipated service life of any of the alternatives (i.e. 80 years for the “Worst Case” scenario and 100 years based on the “Best Case” scenario.)

The LCCA does not consider indirect costs such as user delay costs, vehicle operating costs and accident costs as these are difficult to estimate with accuracy. However, generally, alternatives that require more frequent closures of the bridge to perform maintenance, repair or replacement will also have higher motorist delay and vehicle operating expenses. Accident costs are likely to be similar for designs with similar roadway configurations, roadside safety features, and design speeds.

3.6.2 LCCA Results

The results of the LCCA are summarized in Table 1, below, with the following assessment (see Appendix B for full LCCA):

Alternative 1 has a low initial construction cost, Alternatives 2, 3 and 4 have high initial construction costs, and Alternative 5 has a moderate initial construction cost.

Alternative 1 has moderate to high life cycle costs, Alternative 2 has a high life cycle costs, Alternatives 3 and 4 have moderate life cycle costs, and Alternative 5 has low overall life cycle costs. With the exception of the initial construction costs, which will be funded under the Accelerated Bridge Program, the Town of Chatham is assumed to be responsible for all other life cycle costs.

Alternative 1 provides a relatively short service life requiring complete replacement of the bridge, except the concrete abutments, every 20 to 30 years, due to the need to replace the timber piles. Alternative 2 provides a relatively short service life for the approach spans requiring replacement of the approach spans every 20 to 30 years, due to the need to replace the approach span timber piles. Alternatives 3, 4, and 5 provide significantly greater service life requiring replacement of concrete and steel elements only after 80 to 100 years, although replacement of timber elements are required more frequently. Alternatives 1, 2, 3, and 4 require replacement of the timber wearing surface every 10 to 20 years and replacement of the timber structural deck every 20 to 40 years, where Alternative 5 requires resurfacing of the concrete after 40 years. Each instance the bridge, approach spans, deck, and wearing surface are replaced result in significant disruptions to users, with corresponding user delay costs.

TABLE 1 - LIFE CYCLE COST ANALYSIS SUMMARY								
Alt.	Description	Initial Project Cost (ABP Funded)	Overall Life Cycle Cost (Present Value with 0.8% Discount Rate)		Town of Chatham Responsibility (Present Value with 0.8% Discount Rate)		Duration (c) Btwn. Bridge Closures (yrs.)	
			Worst Case	Best Case	Worst Case	Best Case	Worst	Best
1	Timber Superstr on Timber Substr Timber Bascule Span (a)	$ 8,147,000	$ 28,126,341	$ 22,519,360	$ 19,979,341	$ 14,372,360	10	20
2	Timber Superstr on Timber Substr Steel Bascule Leaf on Conc Pier (b)	$ 11,387,000	$ 32,435,893	$ 29,622,903	$ 21,048,893	$ 18,235,903	10	20
3	Timber Superstr on Conc-Steel Substr Steel Bascule Leaf on Conc Pier (b)	$ 11,047,000	$ 26,839,854	$ 26,241,159	$ 15,792,854	$ 15,194,159	10	20
4	Timber Deck and Steel Stringer Superstr on Conc-Steel Substr Steel Bascule Leaf on Conc Pier (b)	$ 11,189,000	$ 27,466,483	$ 26,573,530	$ 16,277,483	$ 15,384,530	10	20
5	Conc Deck and Conc Beam Superstr on Conc-Steel Substr Steel Bascule Leaf on Conc Pier (b)	$ 10,676,000	$ 23,573,735	$ 22,430,038	$ 12,897,735	$ 11,754,038	40	40

Notes:
a) Alternative provides 19’-4” navigation channel with unlimited vertical clearance with unprotected operating machinery.
b) Alternative provides 25’-0” navigation channel with unlimited vertical clearance and enclosed bascule pier that fully protects operating machinery.
c) Detour of bridge required to perform major work including wearing surface replacement, superstructure replacement, bridge replacement.

4.0 OVERALL CONCLUSIONS AND RECOMMENDATIONS

Table 2 below summarizes how well each alternative satisfies each of the primary project design criteria listed in Article 3.1. The evaluation is graded on the following scale: *Good*, *Satisfactory, Fair*, and *Poor*, in order of best to worst in satisfying these criteria:

RESULTS OF DESIGN CRITERIA EVALUATION							
Alt.	Primary Project Design Criteria Categories						
	Roadway Function & Safety(1)	Context Sensitive(2)	Navigation Function & Safety(3)	Initial Construction Cost(4)	Life Cycle Costs(5)	Maintenance & Service Life(6)	Environment (7)
1	Good	Good	Poor	Good	Fair	Poor	Poor
2	Good	Satisfactory	Good	Fair	Poor	Fair	Fair
3	Good	Fair	Good	Fair	Satisfactory	Satisfactory	Satisfactory
4	Good	Fair	Good	Fair	Satisfactory	Satisfactory	Satisfactory
5	Good	Poor	Good	Satisfactory	Good	Good	Satisfactory

Notes:

1. Alternatives 1 thru 5 equally accommodate improvements in roadway function and safety, including additional roadway and sidewalk width and safety features.
2. Alternative 1 is an all timber solution that would resemble the existing bridge. The other alternatives contain timber in different bridge elements and other features that mitigate the replacement of the NRHP eligible resource. See table below.

CONTEXT SENSITIVE SOLUTIONS - SUMMARY OF BRIDGE ELEMENTS with TIMBER							
Alt.	Approach Substructure	Approach Beams	Deck	Sidewalks	Pedestrian Railings	Traffic Railings	Bascule Span
1	✓	✓	✓	✓	✓	✓(E)	✓
2	✓	✓	✓	✓	✓	✓(E)	✗ (D)
3	✗	✓(E)	✓	✓	✓	✓(E)	✗ (D)
4	✗	✗ (A)	✓	✓	✓	✓(E)	✗ (D)
5	✗	✗ (B)	✗ (C)	✓	✓	✓(E)	✗ (D)

Notes:

A. Steel stringers are obscured by the timber sidewalks.
B. Concrete deck beams are obscured by the timber sidewalks.
C. Concrete deck includes a stamped concrete pattern and color admixtures to simulate a timber deck.
D. Concrete bascule pier contains stone facing and steel bascule leaf is obscured by the timber sidewalk.
E. Denoted timber members are glue laminated (i.e. glulam) timber in lieu of sawn lumber.

3. A letter from the United States Coast Guard dated February 12, 2010, states "… there have been numerous structural and operational issues involving this bridge over the past several years. A design flaw in the original construction of the bridge prevented it from fully opening for passage of vessel traffic resulting in several mishaps wherein vessels sustained damage to their rigging due to hitting the tip of the draw span. In its present condition the draw span cannot fully open to provide unobstructed vertical clearance for the full width of the bridge between fender faces. The Coast Guard, therefore, will seek to promote the optimum navigational opening for any proposed replacement structure." Alternative 1 provides only a 19'-4" navigation opening width with unlimited clearance, which would be unacceptable to the boating

community, and includes non-redundant operating machinery possessing safety and reliability concerns. Alternatives 2, 3, 4 and 5 provide a 25'-0" navigation opening width with unlimited clearance, which is preferred by the boating community and redundant operating machinery that provides a higher degree of safety and reliability.

4. Alternative 1 has a low initial construction cost, Alternatives 2, 3 and 4 have high initial construction costs, and Alternative 5 has a moderate initial construction cost.
5. Per the life cycle cost analysis, Alternative 1 has moderate to high life cycle costs, Alternative 2 has a high life cycle costs, Alternatives 3 and 4 have moderate life cycle costs, and Alternative 5 has low overall life cycle costs. With the exception of the initial construction costs, which will be funded under the Accelerated Bridge Program, the Town of Chatham is assumed to be responsible for all other life cycle costs.
6. Alternative 1 provides a relatively short service life requiring complete replacement of the bridge, except for the concrete abutments, every 20 to 30 years, due to the need to replace the timber piles. Alternative 2 provides a relatively short service life for the approach spans requiring replacement of the approach spans every 20 to 30 years, due to the need to replace the approach span timber piles. Alternatives 3, 4, and 5 provide significantly greater service life requiring replacement of concrete and steel elements only after 80 to 100 years, although replacement of timber elements are required more frequently. Alternatives 1, 2, 3, and 4 require replacement of the timber wearing surface every 10 to 20 years and replacement of the timber structural deck every 20 to 40 years, where Alternative 5 requires only resurfacing of the concrete after 40 years. Each instance the bridge, approach spans, deck, and wearing surface are replaced result in significant disruptions to users, with corresponding user delay costs.
7. Alternatives 1 and 2 include timber piles that will require replacement on more frequent intervals. Replacement of piles disturbs the waterway bottom sediments, which contain accumulations of polycyclic aromatic hydrocarbons (PAHs) and other compounds from the existing piles that are toxic to aquatic organisms. Alternatives 1 and 2 contain a significantly greater number of piles and pile bents than Alternatives 3, 4 and 5, and thus disturb a greater volume of bottom sediments during pile replacement. Although, the concrete bascule pier for Alternatives 2, 3, 4 and 5 is large, the steel sheet pile cofferdam used to construct the pier will contain the sediments and minimize impacts of the disturbed sediments on the environment. New timber piles and other submerged timber substructure elements for Alternatives 1 and 2 may also include timber preservative treatments that are considered hazardous to human health and the environment. Alternatives 3, 4 and 5 include piles and substructure elements with a significantly greater service life and thus minimize the occurrences when the bottom sediments would be disturbed. The piles and submerged substructure elements of Alternatives 3, 4 and 5 avoid the need for hazardous timber preservatives.

Based on evaluation and comparison, the alternatives are generally ranked as follows with regard to the project design criteria:

RANK	ALTERNATIVE
1	Alternative 5
2	Alternative 3
3	Alternative 4
4	Alternative 2
5	Alternative 1

Alternative 5 appears to best satisfy the overall project design criteria. Alternative 5 meets roadway function and safety requirements, minimizes impacts to adjacent properties, provides a cost-effective solution with the lowest overall life-cycle costs, requires least amount of maintenance and corresponding fewest disruptions to users, fully addresses navigation function and safety needs, minimizes impacts to the environment, and provides a context sensitive solution with features that seek to mitigate the replacement of the NRHP eligible resource.

Alternatives 3 and 4 also meet roadway function and safety requirements, minimize impacts to adjacent properties, fully address navigation function and safety needs, and minimize impacts to the environment. In addition, Alternatives 3 and 4 provide a modestly more context sensitive solution than Alternative 5, given the use of timber bridge deck in lieu of concrete bridge deck. However, Alternatives 3 and 4 require greater maintenance with corresponding greater disruptions to users, a higher initial construction cost, and higher life-cycle costs. Alternatives 3 and 4 are virtually equal to each other in construction cost, life-cycle costs, and in meeting project design criteria. However, Alternative 3 provides a slightly more context sensitive solution than Alternative 4 with the use of approach span timber stringers in lieu of approach span steel stringers.

Alternative 2 also meets roadway function and safety requirements, minimizes impacts to adjacent properties, and fully addresses navigation function and safety needs. In addition, Alternative 2 provides a more context sensitive solution than Alternatives 3, 4 and 5 with the use of all timber approach span superstructure, substructure and pile foundations. However, Alternative 2 requires significantly greater maintenance with corresponding disruptions to users, introduces greater environmental impacts, and has the highest initial construction cost, and highest life-cycle costs.

Alternative 1 also meets roadway function and safety requirements and minimizes impacts to adjacent properties. In addition, Alternative 1 has the lowest initial construction cost and is the only solution that provides an all timber single-leaf wooden draw span. However, Alternative 1 has moderate to high life-cycle costs, does not adequately address navigation function and safety needs, requires significantly greater maintenance and corresponding disruptions to users, and introduces the greatest environmental impacts.

As such, URS recommends Alternative 5 is recommended with continued coordination of appropriate mitigation to achieve an appropriate balance of all design criteria.

APPENDICES

A. Existing Plans
B. Life Cycle Cost Analysis (LCCA)
C. Renderings
D. Correspondence
E. References